

Set 10.0: Molar Mass and Compounds

Skill 10.01: Identify the relative number of atoms in a compound given its chemical formula

Skill 10.02: Calculate the molar mass of a compound

Skill 10.03: Convert between moles and mass in grams of a compound and visa versa

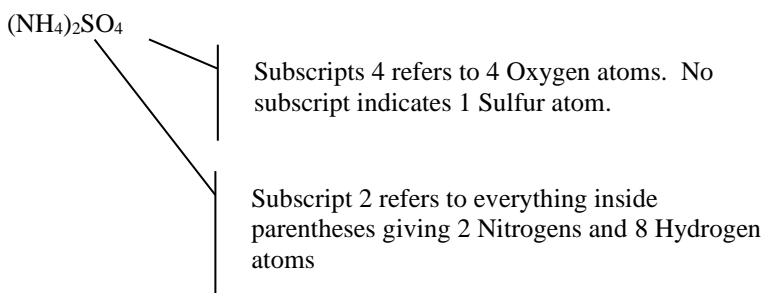
Skill 10.04: Be able to calculate the percent composition of a compound

Skill 10.05: Apply Dalton's law of constant proportion to calculate the mass, moles, and number of atoms in a compound

Skill 10.01: Identify the relative number of atoms in a compound given its chemical formula

Skill 10.01 Concepts

A chemical formula indicates the relative number of atoms of each kind in a compound



Skill 10.01 Example 1

For each of the following compounds, identify the number of each type of atom	
(a) $\text{Al}_2(\text{SO}_4)_3$	
(b) $\text{C}_{12}\text{H}_{22}\text{O}_{11}$	
(c) NaBrO_3	
(d) $\text{Ca}_3(\text{PO}_4)_2$	

Skill 10.02: Calculate the molar mass of a compound**Skill 10.02 Concepts**

Molecular mass is the sum of the atomic masses in a compound. For example the molecular mass of H_2O is

$$2(1.0 \text{ g/mol}) + 16.0 \text{ g/mol} = 18 \text{ g/mol}$$

Knowledge of the molecular mass enables for the calculation of the number of moles or individual atoms or molecules in a given sample.

Skill 10.02 Example 1

What is the mass of 1 mole of the following compounds?
a. NaCl
b. NaNO_3
c. CaCl_2
d. $\text{Al}_2(\text{SO}_4)_3$

Skill 10.03: Convert between moles and mass in grams of a compound and visa versa**Skill 10.03 Concepts**

Knowledge of the mass of the compound enables for the calculation of the number of moles or individual atoms or molecules in a given sample.

The following example is illustrative:

Example: How much in moles is 0.251 g of sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$)?

Step 1: Define your problem by identifying what you are given and what you are asked to find

Given: 0.251 g sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$)

Unknown: moles sucrose

Step 2: First calculate the molar mass of sucrose

$$\text{Molar mass of C}_{12}\text{H}_{22}\text{O}_{11} = 12(12 \text{ g}) + 22(1 \text{ g}) + 11(16 \text{ g}) = 342 \text{ g/mole}$$

Step 3: Use the molar mass to convert from grams to moles

$$0.251 \text{ g} \times \frac{1 \text{ mole}}{342 \text{ g}} = 0.000734 \text{ mole C}_{12}\text{H}_{22}\text{O}_{11}$$

Skill 10.03 Example 1

(a) How many moles of CH ₄ are present in 16.0 g of CH ₄ ?
(b) How much in grams is 0.50 moles of CH ₄ ?
(b) How many molecules of H ₂ O are present in 8.0 g of water
(c) What is the mass of 6.022×10^{23} molecules of carbon dioxide, CO ₂ ?

Skill 10.04: Calculate the percent composition of a compound

Skill 10.04 Concepts

The percent composition by mass of a compound is the percent by mass of each element in a compound.

$$\text{percent composition of an element} = \frac{n \times \text{molar mass of element}}{\text{molar mass of compound}} \times 100\%$$

where n is the number of moles of the element in one mole of the compound.

Skill 10.02 Example 1

What is the percent composition of each element in ammonia, NH ₃ ?

What is the percent composition of each element in calcium nitrate, $\text{Ca}(\text{NO}_3)_2$
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Skill 10.05: Apply Dalton's law of constant proportion to calculate the mass, moles, and number of atoms in a compound

Skill 10.05 Concepts

John Dalton proposed the basic laws that today serve as the foundation for atomic theory. The second of his laws is known as the law of constant composition:

Multiple samples of any pure chemical compound always contain the same percent by mass of each element making up the compound

For example, a 160.0 g sample of copper(I) sulfide (Cu_2S) contains 128.0 g of copper (Cu) and 32.0 g of sulfur (S). The percent by mass of these elements is therefore:

$$\% \text{ copper} = \frac{\text{mass of copper}}{\text{mass compound}} = \frac{128.0\text{g}}{160.0\text{g}} = 80.00\%$$

$$\% \text{ sulfur} = \frac{\text{mass of sulfur}}{\text{mass compound}} = \frac{32.0\text{g}}{160.0\text{g}} = 20.0\%$$

These same percentages are found in any sample of pure copper(I)sulfide, no matter where it comes from or what the size of the sample is. These percentages can be applied to find the mass of the constituent elements in any sample. Let's consider an example,

Example: How many grams of C, H are in 1.00 g of C_2H_2

Step 1: One you know the percentage by mass of C and H in C_2H_2 , you can easily find the mass, moles, or number of atoms in a given sample. The percentage of C and H are,

$$\frac{2 \text{ C} \times 12 \frac{\text{g}}{\text{mol}}}{2 \text{ C} \times 12 \frac{\text{g}}{\text{mol}} + 2 \text{ H} \times 1 \frac{\text{g}}{\text{mol}}} \times 100 = 92.3\% \text{ C}$$

There are only two elements in the molecule so, if 92.3% is C,

$$100 - 92.3\% = 7.7\% \text{ H}$$

Step 2: According to the above result ALL samples of C_2H_2 contain 92.3% C and 7.7% H so, the mass of C and H in 1.00 g of C_2H_2 is,

$$1.00 \text{ g } \text{C}_2\text{H}_2 \times \frac{92.3}{100} = 0.923 \text{ g C}$$

$$1.00 \text{ g C}_2\text{H}_2 - 0.923 \text{ g C} = 0.77 \text{ g H}$$

Skill 10.05 Example 1

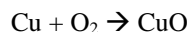
50. g of pure water (H ₂ O) is decomposed into its components, you obtain a 5.6 g sample of hydrogen gas and a 44.4 g sample of oxygen gas.	
(a) What is the percent mass of each of these elements in water?	
(b) What is the percentage of hydrogen and oxygen in a 65 g sample of pure water (H ₂ O)?	

Skill 10.05 Example 2

A 58.5 g sample of a compound of carbon and oxygen is 47.1% by mass oxygen	
(a) What is the percent by mass of carbon in this compound?	
(b) What is the mass of oxygen in the compound?	How many moles of oxygen are in the compound?
(c) What is the mass of carbon in the compound?	How many moles of carbon are in the compound?

Now, let's consider another example,

Example: A strip of copper metal having a mass of 4.767 g was heated in air until all of it was converted into copper oxide according to the following reaction,



The final product (CuO) has a mass of 5.967 g. What is the percent composition? To determine this consider the follow steps,

Step 1. We know how much copper reacted and we also know how much oxide was produced.

$$\begin{aligned}\text{Mass copper} &= 4.767 \text{ g} \\ \text{Mass copper oxide} &= 5.967 \text{ g} \\ \text{Mass of oxygen} &= 5.967 \text{ g} - 4.967 \text{ g} = 1.200 \text{ g}\end{aligned}$$

Step 2. To calculate the percent composition we must divide the mass of each reactant by the mass of the product and multiply by 100.

$$\frac{4.767 \text{ g Cu}}{5.967 \text{ g CuO}} \times 100 = 79.89\% \text{ Cu}$$

$$100 - 79.89 \% = 20.11\% \text{ H}$$

Skill 10.05 Example 3

An ionic compound was prepared by reacting 12.1 g Al with 47.9 g of Cl. What is the percent composition of the ionic compound?

Skill 10.05 Example 4

A student took 10.0 g of an unknown hydrate and heated it in order to drive off the water of hydration. The mass of the anhydrous salt (that's what is left after the water is gone) was 5.82 g.
(a) What is the percent water in the original hydrate?
(b) Which of the following compounds could be the hydrate: $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$
(a)
(b)